Triboelectric Apparatuses for Evaluating Insulators and Minerals

Raymond H. Gompf, Carlos I. Calle, Jon A. Bayliss, and Jeffrey L. Rauwerdink
Materials Science Laboratory
National Aeronautics and Space Administration
Kennedy Space Center, FL 32899

Martin G. Buehler
Microdevices Laboratory
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

Dennis P. Martin
Halcyon Microelectronics, Inc.
Irwindale, CA 91706

Abstract: Three new apparatuses have been designed by the authors to evaluate the triboelectric properties of both insulators and minerals such as Martian soils or other particulates. This effort is in support of the selection of materials for use in space and most recently for the human exploration of Mars. The purpose of this paper is to compare the test results of these test devices and show how the three new devices fill a void in the evaluation of electrostatic materials for space exploration. This paper discusses the triboelectric equipment, the control of parameters, and the reproducibility of results. The data analysis reveals how the Paschen curve affects the triboelectric properties of materials under Martian conditions.

Introduction: Starting in the 1960's, NASA's interest in static electricity was driven by the need to identify materials that are appropriate for use in or around hazardous environments. This need resulted in the development of the NASA triboelectric test device. This device is still used as the electrostatic test method of choice for the aerospace industry. It has been used to determine the acceptance or non-acceptance of several thousand materials. More recently, the characterization of static charging of materials and soils in the Martian environment has been undertaken for the MECA experiment to MARS. These new devices introduced in this report are designed to fill the need to do triboelectric testing on soils and to evaluate the particulate attraction of materials (like solar cells).

The Earth is fortunate in having an atmosphere with a significant moisture content which reduces the probability that static charge will buildup on surfaces. However, in the Martian environment which has only trace amounts of moisture, triboelectric charging of surfaces is expected to be a significant problem. During the Mars Pathfinder mission, the accumulation of dust on solar cells degraded the power output by 10 percent in 60 days. Other effects of dust are the obscuration of windows and face masks and the clogging of thermal radiators. Thus, an effort has been undertaken to develop apparatuses that can be used to characterize static electricity charging of insulating materials.

Apparatus: The four apparatuses are shown in Figs. 1 to 4. In the NASA triboelectric test device, shown in Fig. 1, the test insulator is mounted into a 150-cm diameter aluminum frame. A teflon rubbing wheel is rubbed against the test sample at a known pressure and velocity for a predetermined time after which the sample is moved rapidly to the front of an electrometer for measurement.

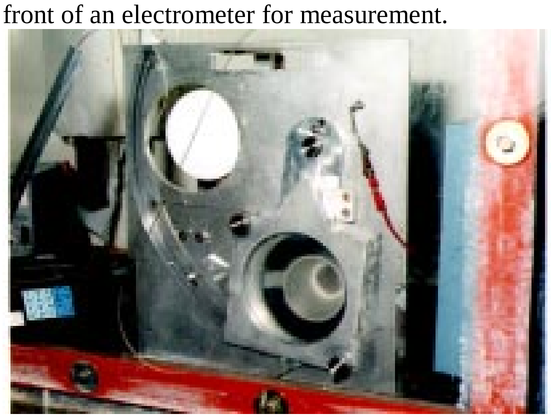

Figure 1. NASA Triboelectric Test Device.

The linear rubbing machine, shown in Fig. 2, uses a MECA/Electrometer. The sample to be tested is mounted on the sample platform and held against the electrometer with a weight. The electrometer head is the same as the MECA electrometer and consists of five individual electrometers and samples of choice for testing. These five samples are dragged across the soil sample (or other material) and the electrometer senses the generated voltage and transmits it to the computer for recording and analysis.

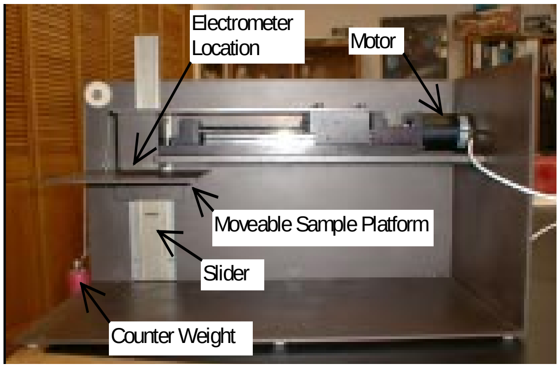

Figure 2. Linear rubbing machine with moving insulator head.

Another linear rubbing machine, shown Fig. 3, has the MECA/Electrometer mounted so that it can move vertically. It is self-weighted. The test insulator, wool felt, is moved against the electrometer head to generate the electrostatic voltage for analysis.

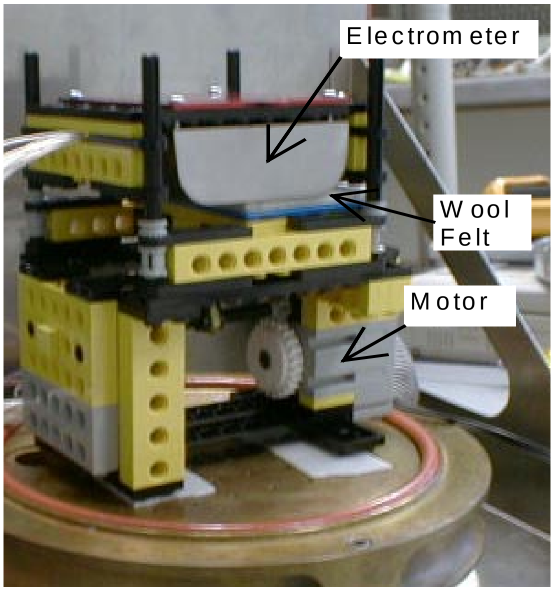

Figure 3. Linear rubbing machine with fixed electrometer. The wool felt is rubbed against the MECA/Electrometer insulators.

The rocking machine, shown in Fig. 4, is designed to test the electrostatic properties of particulate material. It is rocked back and forth so that the minerals move across the insulators shown at the bottom of the chamber. The rubbing material is held in place by gravity acting on the particles. The electrometer is again the MECA Electrometer similar to the one used in the rubbing machine. A modification to the device replaces one or more electrometers with photoelectric cells to determine the reduced light transmission due to particulate blockage. The relationship between dust blockage and triboelectric properties will be discussed in the report

Figure 4. Rocking apparatus with basalt loaded on the MECA/Electrometer shown in Fig. 6.

Model: The model for the triboelectric rubbing devices, shown in Fig. 5, indicates that a number of parameters must be controlled to achieve repeatable measurements. The test insulator is grounded around its periphery. The major parameters are:

1. Insulator surface preparation
2. Atmosphere gas
3. Atmospheric pressure
4. Moisture
5. Atmospheric temperature
6. Contact pressure.
7. Velocity during contact

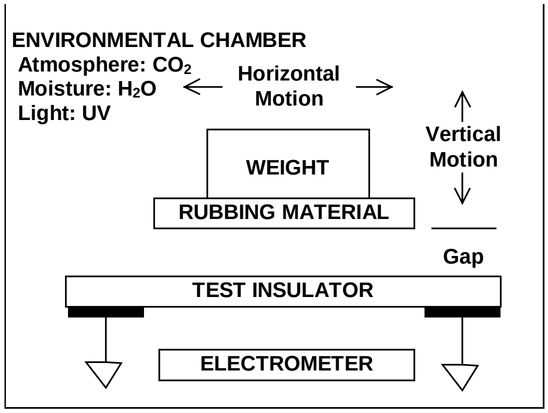

Figure 5. Elements of a triboelectric rubbing machine.

Experimental Results: The results presented here were taken using the MECA/Electrometer shown in Fig. 6. It has five insulators mounted across in its titanium housing.

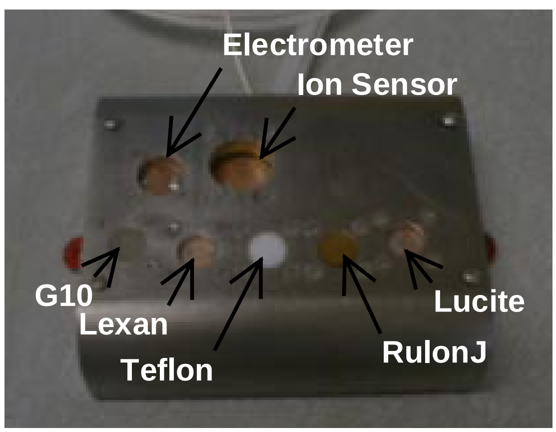

Figure 6. MECA/Electrometer with five insulators, and electrometer and ion sensor.

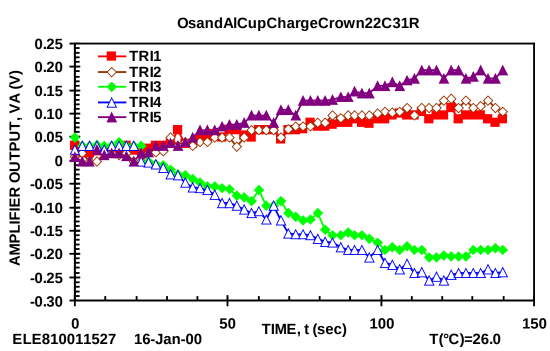

Figure 7. Ottawa sand: Results due to contact triboelectrification.

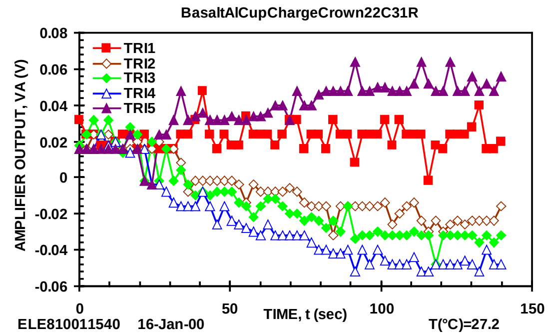

Figure 8. Basalt: Results governed by contact triboelectrification.

Conclusion: Each of the four apparatuses shown here have unique advantages. The NASA triboelectric device is well adapted to thin films and solid materials that range from semiconducting insulators (antistats) to insulators. The linear rubbing machine, shown in Fig. 2, keeps a known pressure at the contact interface during rubbing. It can be located inside an environmental chamber that controls temperature, pressure and moisture. The linear rubbing machine, shown in Fig. 3, is small and inexpensive. The rocking machine, shown in Fig. 4, is also small and inexpensive to manufacture. It can be located inside an environmental chamber and has the ability to measure light transmission of materials after subjection to particulate comtamination.

Acknowledgments: The work described in this paper was performed by the Materials Science Laboratory at KSC and by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The authors are indebted to the managers who have encouraged this work.